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MECHANISMS OF WATER-SALT METABOLISM DISTURBANCES IN DOGS SUBJECTED TO SIX-MONTH HYPOKINESIA

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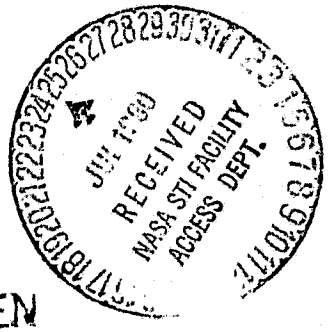

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16. Abstract

A prolonged limiting of the motor activity decreased the organism hydration, led to fluid redistribution between its extra- and intracellular sectors. Electrolyte excretion rose. Magnesium and calcium metabolism changed more significantly. Apparently, forces caused by the muscle strain proper (which was decreased under conditions of hypokinesia) influence the state of bone metabolism.

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MECHANISMS OF WATER-SALT METABOLISM DISTURBANCES IN DOGS SUBJECTED TO SIX-MONTH HYPOKINESIA

By

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It is known that hypokinesia, disrupting the nature of the intersystem inter- /32*
relationships results in the appearance of disorders on the part of the neuro-endocrine and cardiovascular systems, in changes in the structural and energy supply for the functions. In pathogenesis of the noted disorders the shifts in the water-salt metabolism occupy a special place.

In humans under conditions of a prolonged bed confinement the observed changes in the water-salt metabolism can be a consequence of two reasons: the actual immobilization and the movement of the liquid media of the organism that occurs with a change in body position in relation to the vector of terrestrial gravity. The conducting of experiments on animals whose constant horizontal body orientation is not altered during simulated hypokinesia can promote a pinpointing of the role of the effect of the motor component on the water-salt metabolism. In addition, in animals under conditions of restricted motor activity the support function of the skeleton remains unchanged. This is very important for a differentiated study of the main links in the pathogenesis of the disorder in mineral metabolism in man during his bed confinement; is it due to elimination of the support function of the skeleton or is it a result of the decrease in muscle stresses applied to the skeletal bones. As a rule, little attention is paid to the latter circumstance.

The purpose of this study was to investigate the water-salt metabolism in animals during their prolonged restricted motor activity.

*Numbers in margin indicate pagination in original foreign text.

Technique

The experiments were conducted on 12 male dogs weighing 6-9 kg, whose motor activity was restricted by staying in special devices that permitted the animal to adopt the positions "lying down," "sitting," and "standing." The animals were exposed to clinical examination, selection and multiple repeated training. Therefore in the first days of the experiment in the majority of the dogs no "anxiety reaction" was observed and they stayed calmly in the fixing devices.

Studies of metabolism were conducted 6 times: in the initial period, on the first-fourth, 14th-18th and 25th-30th days, as well as at the end of the second and third months of hypokinesia. In these periods calculation was made of the quantity of consumed food and the water content in it, the quantity of released excrement and urine. The method of flame spectrophotometry was used to determine the content of potassium, sodium, calcium and magnesium in the food, excrement and urine.

Before the beginning of the experiment, in 1, 3 and 6 months of stay by the animals under conditions of restricted motor activity the quantity of total water in the body (TWB) was determined with the help of tritium oxide (10μCi per 1 kg of body weight), volume of extracellular fluid (VEF) and volume of circulating plasma (VCP) by the method of dilution respectively of sodium thiocyanate and dye T-1824. Simultaneously the determined hematocrit index made it possible to evaluate the value of the volumes of circulating blood (VCB) and erythrocyte mass (VEM).

Analysis of the uniformity of dispersions for each index in the process of the experiment was made with the help of the Kokhren criterion [5]. This permitted the further correct use for processing the material of the Student's test.

Results and Discussion /33

By the end of the first month of stay by the animals under conditions of restricted motor activity the VCB was reduced by 21.6% as compared to the original amount, which was due to a decrease in the VCP by 24.2% and the VEM by 16.9%. It is interesting that in the case of a violent reaction to the fixing (dog Svetlaychok) the condition of stress and increased motor activity resulted in the opposite changes: VCB was increased by 41.6% of the initial due to the rise in VCP and VEM

respectively by 42.2 and 38.4%.

Within 3 months the volume of intravascular fluid in the majority of dogs was 69.6% in relation to the initial amount and was maintained low up to 6 months, i.e., a seeming stabilization of its on a lower level occurred.

Restricted motor activity in the dogs also affected the hydration status of the organism. In a comparison of the data in the same dogs before the experiment and after 30-day hypokinesia the quantity of TWB was reduced by 4% ($P<0.02$) (with initial value 66.2 ml per 1 kg of body weight of the animal). In the dog with increased activity an increase was noted in the specific quantity of fluid (in calculation per unit of body weight)--by 12.2% with a sharp reduction in its total content in the organism. This, apparently, is linked to the fact that a considerable weight loss in the given period (8.4%) occurred mainly due to the poorly hydrated fatty tissue. In the subsequent periods the quantity of fluid was reduced even more, in 3 months comprising 90.1% ($P<0.02$) and in 6 months of hypokinesia 90.9% ($P<0.01$) as compared to the initial amount. The hydration status of the organism in these periods was reduced also in the dog Svetlyachok). It should be noted that there were no differences in the fluid content in the organism between the third and sixth months of restricted mobility.

The VEF by the end of the first month of hypokinesia was reduced by 17.6% ($P<0.001$) with initial value 30.2 ml per 1 kg of body weight, and volume of the intracellular fluid at the same time was increased. Within 3 and 6 months the intracellular content of fluid in the organism was reduced in all the dogs by 30.1% ($P<0.05$) and 16.2% ($P>0.1$) respectively, while the intracellular content exceeded the background amount respectively by 1.3 and 3.6%. The increase we noted in the content of intracellular fluid, possibly, is linked to the dominance of the catabolic processes, as a result of which an increased quantity of endogenous water is formed in the cell. In addition, in the case of intensified breakdown of protein in the cell the quantity of osmotically active particles also rises, which can govern the movement of water from the intermediate space into the cells [3].

Restricted motor activity in the dogs resulted in a pronounced increase in excretion of all the studied electrolytes. However, the nature of the increase was not the same: the potassium and sodium metabolism were altered to

a lower degree--the exceeding of the original level was only 16-19%, while the excretion of magnesium and calcium whose main depot is the bones, exceeded the background amount by 20-43% (see table). One should note another interesting law in the dynamics of the change in excretion of the given pairs of electrolytes: the peak of increase in potassium and sodium excretion occurred on the 25th-30th day of hypokinesia; by the end of the third month their excretion had returned to the original. Excretion of magnesium and calcium on the 25th-30th day of the experiment was 120-130% as compared to the initial level, and by the end of the third month of hypokinesia was either maintained on the same level (magnesium) or was increased even more (calcium), comprising 143% of the background. The data we obtained agree well with the results of the studies made on other species of animals by a number of authors [4,6,8] who observed a rise in excretion from the /34
organism of sodium, phosphorous and especially calcium during hypokinesia.

In relation to the fact that we not only knew the quantity of the excreted electrolytes, but also strictly calculated the salt composition of the food ration it was possible to study the balance metabolism of electrolytes in these animals. The balance of potassium and sodium, dropping in the process of hypokinesia, especially noticeably on the 25th-30th day, nevertheless remained positive during the entire period of the experiment. Disturbances in the metabolism of magnesium and calcium were more pronounced. The balance of magnesium in individual periods of hypokinesia approached zero, while calcium even became negative.

In analogous experiments on rats it was also found that in the process of 90-day restricted mobility the sodium metabolism on the whole remained positive, although on individual days of hypokinesia the release of sodium from the organism insignificantly surpassed its input [1]. However, in rats, judging from the data of a number of authors [6], in the process of restricted mobility the balance of magnesium and calcium remained positive, although it was considerably reduced. More pronounced changes in the metabolism of electrolytes in our experiments, apparently, can be explained by the different initial functional state of the organism--usually the motor activity of the dogs significantly surpasses that in the rats. In addition, it is possible that the experimental results were affected also by method differences: increase in duration of the periods of metabolic studies, naturally, makes it possible to judge with greater probability the true nature of the state of the balance relationships of individual electrolytes.

TOTAL REMOVAL OF ELECTROLYTES, mlequiv/day (M±m)

	Background	Hypokinesia (days)				
		1—4	14—18	25—30	58—62	88—92
Potassium	25,2±0,93	26,0±1,71	29,5±0,72*	30,1±0,81*	29,2±0,41*	27,0±1,58
Sodium	68,1±1,27	70,7±2,73	74,0±2,93	79,3±2,54*	72,4±1,43	69,6±3,44
Calcium	17,6±1,61	18,5±2,07	21,6±1,57	23,0±2,76	24,5±1,41*	25,3±3,95
Magnesium	5,[illegible]5±0,34	5,86±0,44	6,52±0,36	7,0±0,27*	6,48±0,33	6,95±0,74

Note. Asterisks mark the indices that reliably differ from the corresponding indices of the background.

The zero balance for magnesium and the negative for calcium, apparently, were a result mainly of certain destructive changes in the bones that usually were observed in the restricted mobility of other species of animals [7]. The reason for the potassium deficit in the organism in the dogs was more likely the reduction in the total muscle mass as a result of its atrophy from inactivity, although one cannot also exclude the possibility of reduction in its concentration in the muscle tissue [2,3].

Thus, the findings indicate that under conditions of prolonged hypokinesia pronounced and distinct changes occur in the hydration status of the organism of animals and a redistribution of the fluid is noted between its different sectors. Despite the preservation in the animals under conditions of hypokinesia of the /35
support function of the skeleton, the reduction in motor activity results in the emergence of explicit disorders inthe state of salt metabolism. Especially sharp changes in the process of hypokinesia are revealed on the part of the metabolsim of magnesium and calcium. This, apparently, is linked to the fact that the condition of bone metabolism is affected by forces governed not only by the weight load, but also by the actual muscle stress whose amount is sharply reduced under conditions of restricted mobility. Consequently, the muscle activity is an important condition for normalization of the metabolic processes in the bone tissue, including in its mineral component. At the same time the sharp decrease in the volume of the muscle function in itself, even without a change in the body position, as we see, can become one of the important pathogenetic links inducing a chain of significant changes on the part of the water metabolism and the balance of electrolytes.

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